NASA-CR-203243

REDETERMINATION OF FLUXES FOR IRAS GALAXIES

FINAL
7N-89-CR
0017
071240

(NAG 52403)

Final Report

Amos Yahil

Astronomy Program, State University of New York, Stony Brook, NY 11794 2100

1. Summary

One of the most important discoveries of the Infrared Astronomical Satellite (*IRAS*) has been the detection of about 20,000 galaxies with 60μm fluxes above 0.5 Jy. From the observational point of view, the *IRAS* galaxies are ideal tracers of density, since they are homogeneously detected over most of the sky, and their fluxes are unaffected by galactic extinction. The nearby universe has now been mapped by the *IRAS* galaxies to a distance $\sim 200h^{-1}$ Mpc for $|b| > 5°$. The ability to map down to such low galactic latitudes has proven to be particularly important, since some of the most important nearby large-scale structures, such as the Great Attractor, the Perseus-Pisces region, and the Shapley concentration, all lie there.

I have been active in this field since its inception, first showing on the basis of positions and fluxes that the *IRAS* dipole was aligned, within the errors, with the dipole anisotropy of the microwave background radiation (Yahil, Walker, & Rowan-Robinson 1986), and then initiating an extensive, multi-year, redshift survey in collaboration with M. Davis, K. Fisher, J. Huchra, & M. Strauss, which provided the 3-d density maps. (A parallel effort has been undertaken by a British-Canadian collaboration known as QDOT.)

The sample for the U. S. *IRAS* redshift survey was initially defined using fluxes from the Point Source Catalog (PSC), with ADDSCANs performed on a subset of the sample to improve the fluxes. In the conversion from galaxy counts to density, the flux error was assumed to be a constant fraction of the flux. This was a good initial procedure, and the results speak for themselves. But as we move on to confront the derived density field more closely with theory and with other data, we need to remove systematic errors that were glossed over before. The major areas of concern are the underestimate of fluxes of extended nearby galaxies, noise due to confusion at low galactic latitude, and systematic errors at large distances.

This project sought to reduce the systematic errors in the derived *IRAS* density field

by: (1) obtaining realistic unbiased measurements of fluxes for extended nearby sources, whose fluxes are underestimated by the point source template, (2) taking account of confusion with other sources in the beam, primarily foreground cirrus in our own Galaxy, (3) recognizing that flux errors are position and flux dependent, particularly at lower galactic latitudes, and obtaining an individual estimate of flux error for each source, and (4) determining the completeness of the catalog as a function of both flux and position.

There are errors in the *IRAS* density field due to four effects (Davis, Strauss, & Yahil 1991; Strauss *et al.* 1992a): (1) sampling (shot) noise due to the finite number of galaxies, (2) uncertainties in the derived selection function and average density, (3) uncertainties in the correction for peculiar velocities, and (4) regions of the sky not covered by the survey.

The largest *statistical* error is due to sampling noise (Dekel *et al.* 1993). This noise can be reduced somewhat by increasing the sample size (the QDOT project). Here we are concerned with *systematic* errors, which can be traced primarily to flux errors, affecting both the sample definition and the conversion from galaxy number counts to spatial densities via the selection function.

First, the fluxes of extended galaxies, e.g., the ones in the Local Supercluster, are systematically underestimated by the *IRAS* Point Source Catalog (PSC). While we have attempted to compensate for this error by obtaining ADDSCAN/SCANPI fluxes for a significant fraction of our sources, we did not ADDSCAN all of them, and the criteria by which sources were chosen for ADDSCAN were not always optimal. We were particularly concerned about sources whose PSC fluxes are below the 1.2 Jy limit, hence were not included in our sample, but would be if the SCANPI flux were available and above 1.2 Jy.

Yahil *et al.* (1991) describe our method for finding the selection function. It is computed at each distance as an integral over the luminosity function, as truncated by the flux limit. But we select galaxies on the basis of their *measured* luminosities, not the true ones. Hence the relevant luminosity function is a convolution of the true luminosity function and the flux error function. We have so far taken the flux error to be proportional to flux (*IRAS* Explanatory Supplement 1988, Table VII.D.2). In that case, the convolved luminosity function is independent of distance, and one need never consider the true luminosity function (Strauss, Yahil, & Davis 1991).

We have found, however, that the proportionality of flux error to flux breaks down at low fluxes, first leveling off with decreasing flux, and then even rising somewhat. Failure to account for this effect in the selection function leads to a systematic error in the derived density as a function of distance which mimics evolution (Fisher *et al.* 1992).

The situation is even worse, because a non-negligible fraction of the sources are confused by the presence of another source within the beam, usually foreground cirrus. Neither the PSC nor the SCANPI fluxes fully account for this confusion, as detailed inspections of problematic ADDSCANs have shown.

Needless to say, confusion becomes more severe closer to the galactic plane, and the flux error function is therefore broader there. This introduces a directional bias, in addition to the distance bias. Unfortunately some of the most interesting nearby large-scale structures, such as the Great Attractor, the Perseus–Pisces region, and the Shapley concentration, all lie at low galactic latitudes.

In view of the above difficulties the fluxes of *all* the *IRAS* galaxies were thoroughly re-evaluated. First, the most accurate unbiased flux was sought for any source that may be a galaxy. Proper account was taken both of the possible finite extent of the galaxy (relative to the beam), and confusion with other source(s). If the confusing source(s) could not be "fitted away", the target source was flagged for more detailed investigation. Secondly, a realistic flux error distribution was assigned to each source, so that the selection function could reliably be computed on a per source basis as a convolution of the true luminosity function and the flux error function. Finally, for the sake of deeper samples, such as the QDOT surveys, the completeness of the catalog was studied as a function of direction.

The sample was defined as all sources in the Faint Source Database (FSDB) with

$f_{60} > 0.4$ Jy and $|b| > 5°$. To this were added a handful of sources from the PSC that were not in the FSDB and a small number of sources with $f_{60} < 0.4$ Jy near the Galactic poles, for a total of 49,692 sources.

It became clear from extensive discussions with IPAC that it would be very man-power expensive to change any of their basic software. Instead, we used the existing software, and performed post-processing analysis on the output obtained from IPAC. IPAC ADDSCANed all the sample sources for us and we fitted the ADDSCANs.

Our code fits a broadened instrumental point source template to the ADDSCANs in the Fourier transform k-space, instead of in the original scan space. The code is very robust and has fitted all the sample sources without a hitch. It is also very efficient, processing 1000 sources per hour on a DECstation 3100 workstation, all the way from the input IPAC ADDSCAN/SCANPI tape to the final output file. Both the code and the resultant catalog are available from IPAC.

The large source list was then culled to obtain a galaxy sample as follows: (1) flux limit $f_{60} > 1.2$ Jy (or 0.6 Jy for QDOT), (2) color: $f_{60}^2 \geq f_{12} f_{25}$, (3) width criterion: $(\delta w)^2 \leq 0.2 \text{arcmin}^2$, and (4) outside an exclusion zone consisting of $|b| < 5°$ (8.7% of the sky), areas of low *IRAS* coverage (1.9%), and areas with below 99% completeness at 1.2 Jy (3.0%). The color criterion is useful in separating stars from diffuse emission (galaxies and cirrus), while the width criterion removes cirrus contaminants, and eliminates less than 1% of real galaxies. The resulting galaxy candidate sample consisted of 6,601 sources.

Optical identifications and further checks for duplicate and bogus sources and large galaxies (Mancinelli 1996) yielded a final flux-limited sample of 5,693 galaxies, of which 5,634 have measured redshifts. (The remaining 59 sources are concentrated within $\sim 15°$ from the plane, and are likely mostly cirrus.) This is an increase of more than 300 galaxies with redshifts over the original 1.2 Jy sample.

The major conclusion from an analysis of the new 1.2 Jy sample of galaxies (Mancinelli

1996) is to confirm the previous determination of the *IRAS* density field, so that the estimates of the cosmological density parameter Ω and bias factor b are not significantly different than previous estimates, despite improvements in the flux determination and the sample selection. The large smoothing necessary for the comparison of the galaxy and mass density fields washes out any small-scale differences that may be present. Additionally, the very large-scale (external) distribution of matter has little effect on the gravitational field of the nearby universe within the volume in which the density and velocity fields have been compared. The change in the predicted velocity field is $\lesssim 80$ km s^{-1} for distances $\lesssim 8,000$ km s^{-1}.

Further analysis of the large-scale density field determined that this field could be reliably measured with the 1.2 Jy survey out to ~25,000 km s^{-1}. The density relative to the mean density starts to drop off at this distance, predominantly due to contamination near the Galactic plane, where it becomes difficult to identify faint (distant) galaxies in the midst of infrared cirrus clouds.

The expected motion of the Local Group (LG) relative to galaxies within 12,800 km s^{-1} is expected to be $\sim 880\Omega^{0.6}/b$ km s^{-1} toward the Galactic coordinates $(l, b) = (250°, 50°)$, which is not inconsistent with the proposition that the observed CMB dipole is caused by this motion. The data suggest that the peculiar velocity of the LG arises from the gravitational field induced by the density perturbation field. By equating the CMB dipole to the peculiar velocity of the LG, a crude estimate of $\Omega^{0.6}/b \approx 0.7$ can be derived.

A simulated 0.6 Jy survey was created from the FSDB using our new fluxes and simulated redshifts to determine whether flux errors would severely affect the density field determination using the QDOT *IRAS* 60μmGalaxy Catalog. As in the case of the 1.2 Jy sample, the simulated 0.6 Jy sample is essentially unaffected by flux errors. Deviations of ~0.1 in the fractional density field (relative to the field derived without flux errors) and ~100 km s^{-1} in the peculiar velocity field can be expected.

This project had the markings of a mature field. Barring some theoretical revisions, particularly the use of nonlinear dynamics to separate the effects of cosmology from galaxy biasing, the goal was not to blaze new trails as was done in the first few years. Instead, the objective was to refine the measurements, and weed out possible systematic errors. The result has been renewed confidence in the density field derived from the *IRAS* data, securing the determination of the primary cosmological parameters: Ω and the primordial power spectrum.

REFERENCES CITED

Davis, M., Strauss, M. A., & Yahil, A. 1991, ApJ, 372, 394

Dekel, A., Bertschinger, E., Yahil, A., Strauss, M. A., Davis, M., & Huchra, J. P. 1993, ApJ, 412, 1

Fisher, K. B., Strauss, M. A., Davis, M., Yahil, A., & Huchra, J. P. 1992, ApJ, 389, 188

IRAS Explanatory Supplement 1988, eds. C. A. Beichman, G. Neugebauer, H. J. Habing, P. E. Clegg, & T. J. Chester (Pasadena: JPL)

Mancinelli, P. J. 1996, Ph.D. thesis, University at Stony Brook

Strauss, M. A., Davis, M., Yahil, A., & Huchra, J. P. 1992a, ApJ, 385, 421

Strauss, M. A., Yahil, A., & Davis, M. 1991, PASP, 103, 1012

Yahil, A., Strauss, M. A., Davis, M., & Huchra, J. P. 1991, ApJ, 372, 380

Yahil, A., Walker, D., & Rowan-Robinson, M. 1986, ApJ, 301, L1